

Comments on "Venus" Spectroscopic Phase Variation:  
Implications of the Mariner 10 Photographs"

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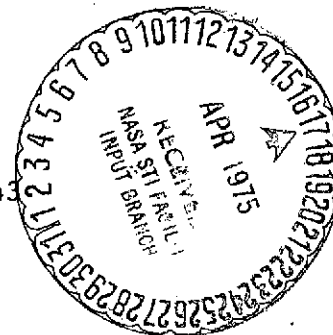
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COMMENTS ON "VENUS' SPECTROSCOPIC PHASE VARIATION: IMPLICATIONS  
OF THE MARINER 10 PHOTOGRAPHS"

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ABSTRACT

From a misinterpretation of Mariner 10 pictures, Chamberlain (1974) has constructed a model in which he uses horizontal variations in the Venus atmosphere to explain the phase-variation of CO<sub>2</sub> absorption at small phase angles. Published observations of spatial variations in CO<sub>2</sub> absorption on Venus show that they are too small to explain the phase effect. Chamberlain also raises the question of uniqueness, viz., can more than one model explain the phase-effect observations? Before this question can be answered, we must have at least one realistic model that does account for the data. Unfortunately, no such calculations exist.

Subject headings: atmospheres, planetary  
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## I. Introduction

Chamberlain (1974) has based a model of the Venus atmosphere on a misinterpretation of Mariner 10 pictures. These pictures (Murray et al., 1974) show the ultraviolet features discovered by Ross (1928) in more detail than is available in ground-based pictures. Although there are some superficial similarities between details shown on Venus by the Mariner 10 pictures and those seen in spacecraft pictures of terrestrial clouds, I regard the implied analogy between clouds on the two planets as dangerous and unwarranted. Terrestrial clouds, seen from space, show high contrast with the much darker planetary surface which is seen between them; moreover, this high contrast is maintained over a broad spectral region. On the contrary, the cloud features on Venus are seen only at short (near-UV) wavelengths and are completely invisible in visible light, both on ground-based and on Mariner 10 pictures. Furthermore, the maximum contrast of the UV features on Venus does not exceed 30%, according to Murray et al. (1974).

Clearings occur between clouds on Earth because the cloud material can evaporate completely when it is heated a few degrees, e.g., in downdrafts between cumulus towers. But if clouds on Venus are made of strong sulfuric-acid solutions, as is now generally accepted, a few degrees' warming serves only to concentrate the acid slightly, without altering the size of the droplets much. According to the Venera 8 data (Marov et al. 1973), the cloud base occurs near the 400°K level, which corresponds to expectations

for a sulfuric-acid cloud if the water-vapor mixing ratio is near  $10^{-4}$ , according to Fig.8 of Young (1973). As no optical temperature measurement of modern quality has even exceeded  $300^{\circ}\text{K}$ , it is obviously wrong to speak of "clearings" or "holes" in the clouds; we never see down to anywhere near the cloud base, and the cloud cover is continuous.

Indeed, it is probably wrong to assume that we see to different depths in the light and the dark UV features. It must be emphasized that we do not, at present, know whether these features are due to variations in concentration of the (still unidentified!) ultraviolet absorber, to variations in size of the cloud particles (as suggested at the 1974 DPS meeting by J.E.Hansen), to variations in vertical structure of the clouds, or to some other, unknown, mechanism. Perhaps the vertical distribution of the ultraviolet absorber varies from place to place, and the gross cloud structure remains essentially fixed. In particular, as neither ground-based nor Mariner 10 pictures show these features at longer visible or infrared wavelengths, there is no reason to expect to see marked differences in near-IR  $\text{CO}_2$  absorptions between dark and light UV features.

This is borne out by the published data. In an intensive patrol of spectroscopic variations on Venus in September and October of 1972, L.G.Young et al.(1973) found only a few per cent variation in  $\text{CO}_2$  absorption over the planet on any one day, although an effort was specifically made to observe both dark and bright UV features. More extensive data from this patrol have recently been published (A.T.Young et al., 1974). The absorptions were slightly weaker over the equatorial region, but the mean difference from higher latitudes is less than 5%. A detailed analysis (in

preparation) indicates only  $(1 \pm 3)\%$  difference in  $\text{CO}_2$  absorption between areas that appear light and dark on photographs taken in ultraviolet light.

As far as the  $\text{CO}_2$  absorptions are concerned, the UV markings might as well be painted on an otherwise uniform surface with pale yellow paint.

The above observations do show a slight gradient from terminator to subsolar point, amounting to less than 10%. Although this gradient is in the sense of the horizontal variations suggested by Chamberlain (1974), other data show that this is not a permanent feature of the Venus atmosphere. For example, the data published in L.G.Young's (1972) review, which Chamberlain (1974) cites as evidence of a decrease in absorption at small phase angles, clearly show a larger  $\text{CO}_2$  absorption in the center of the disc (subsolar region) at small phase angles than at the limbs. This horizontal variation, in the very data that Chamberlain adduces as evidence of the effect he is trying to explain, is in the sense opposite to that which his explanation requires.

These data raise another cautionary point. The 1972 ground-based patrol, which provided synoptic data on Venus at the same phase angle as the Mariner 10 pictures, but with nearly three times longer coverage, consistently show atmospheric gradients (more absorption in the southern than in the northern hemisphere; less absorption in the subsolar region) that are contrary to those seen at other apparitions (cf. Figs. 7 and 9 of Young, 1972). This means that the conditions observed over the short time span of the Mariner 10 pictures may not be typical of a long-term average of the Venus atmosphere. One should be exceedingly

reluctant to draw sweeping conclusions from data taken on only one or, at most, a few, days. Unfortunately, this is just what most of the interpreters of Venus spectra, cited by Chamberlain (1974), have done.

#### UV vs. IR Clouds

Although the observations cited above suffice to reject Chamberlain's model, it may be worth while to discuss the relation between what we see at different wavelengths a bit further, as there is widespread misunderstanding on this point. The work of Hansen and Arking (1971), recently extended and refined by Hansen and Hovenier (1974), shows that (1) the cloud particles are all "large" compared to the wavelengths of light from the near IR to the near UV; and (2) essentially the same mass of gas, as judged from the Rayleigh-scattered component of polarization, is seen at every wavelength in this interval. Furthermore, the effective "cloud-top" pressure, by which is meant the pressure at optical depth unity, is about 50 mb. This value, derived from polarization data, is in good agreement with the effective pressure of line formation found from spectroscopic arguments by L.G.Young (1972), about 30 to 50 mb. The agreement of these two completely independent methods should not be surprising, for the large particle size and small Rayleigh-scattering component found by Hansen and his co-authors shows that the optical depth in the Venus atmosphere is nearly independent of wavelength in our spectral region. Thus we see the same part of the atmosphere at both infrared and ultraviolet wavelengths, as well as in the visible.

A variety of data indicate that the aerosol is, to a first

approximation, uniformly mixed for two or three scale heights above this level -- i.e., to the region (3 to 5 mb) which we see at the extreme limb of the planet (Young, 1974). From the lack of horizontal variations seen at this level in the Mariner 10 pictures, one can use the uniform mixing ratio of the aerosol to infer a lack of horizontal structure at the 50 mb level as well. This, of course, is consistent with the weakness of CO<sub>2</sub> variations over the disc. As the variations in UV absorption often have higher contrast than the spatial variations in CO<sub>2</sub> absorption, and are weakly, if at all, correlated with the latter, the UV features seem more likely to represent a nonuniform distribution of the UV absorber, rather than being related to cloud structure. (The UV features were unusually prominent during the 1972 patrol referred to above.) Thus, it does not seem useful to try to explain the spectroscopic phenomena with models based on UV pictures, even though we see the same region of the atmosphere in both cases.

#### The Uniqueness Problem

As I see it, the uniqueness question is whether different cloud models are equally consistent with the data. However, it is pointless to construct artificial models, with no resemblance to reality, and then contend that one particular kind of data (e.g., spectroscopic phase curves) cannot distinguish between them. Such models must be ruled out on other grounds. For example, models that employ isotropic scattering must be rejected today, for we now know the single-scattering characteristics of the Venus aerosol quite accurately from Hansen's work. Similarly,

homogeneous (constant-pressure) models must be rejected, not only because of the strong indications that the aerosol is spread over several scale heights (Young, 1974), but also because some of them contain internal contradictions. For example, the theory employed by Chamberlain and Kuiper (1956) is based on the assumption that the ratio of the line to the continuum extinction coefficient is constant throughout the atmosphere at each wavelength. This condition cannot be met in a real atmosphere, for a constant line profile requires a constant pressure; this requires that the region of interest be shallow compared to a scale height. But in this case, most of the absorption takes place in the gas above the cloud, which then acts merely as a simple reflecting layer. The same problem arises for all the "homogeneous" models. On the other hand, the various multi-layered models fail to take account of the angular dependence of scattering in a realistic way.

Furthermore, no recent theoretical discussion has actually compared the extensive observational data (cf. L.G.Young, 1972) with model calculations. Several discussions have attempted to deduce cloud structure from observations taken at only one (or at most, a few) phase angles. If one is to draw conclusions from theoretical models, should he not be obliged to compare them with all the data, rather than merely some subset that happens to fit the model, or even no data at all?

When realistic calculations, based on a physically plausible



model, are shown to fit all the published data within the scatter of the latter, we will have one plausible explanation. If a second such model should be shown to fit the data equally well, then we will have a uniqueness problem. But it is my experience in talking to theoreticians that when you point out some discrepancy between the data and their theories, they excuse it by saying it's caused by some approximation they had to make. I am left with no basis to judge whether the theory is good or bad.

It is my view at the present time that we do not have one adequate theoretical explanation of the spectroscopic observations of Venus, much less the multiplicity of such explanations that would raise the uniqueness problem. I believe the multiplicity of inadequate theories is due to the theoreticians' propensity for solving an unreal problem which is tractable, instead of tackling the much more difficult problem presented by the real world.

Perhaps an examination of the data may help to guide the theoretical effort toward realistic, but still helpful, assumptions and simplifications. For example, the smallness of the <sup>mean</sup> variations over the disc, compared to the features of the phase curve, suggests that it would be useful to do realistic calculations just for the geometry at, say, the mirror point on the disc, instead of trying to integrate over the entire surface of the planet. At the same time, an awareness of the large temporal changes, some of which occur on quite a long time scale, would be beneficial in releasing the theoretician from the grip of spacecraft data which represent the state of the atmosphere

at only one particular moment.

### Conclusion

The Mariner 10 pictures probably have little relevance to infrared spectroscopic observations of Venus. Both of the numbered conclusions in Chamberlain's abstract are incorrect. Spatial variations across the atmosphere of Venus are largely random, though they may be long-lived (weeks to months); any long-term average gradients in the horizontal direction are too weak to measure at present. As there is no satisfactory explanation of the spectroscopic observations of Venus, it is premature to raise the question of uniqueness.

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